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Evidence for $B_s^{(*)}$ Production at the $\Upsilon(5S)$

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Based on data collected by the CLEO III detector at CESR, we started a series of investigations to open the mysteries of the $\Upsilon(5S)$ resonance decay properties. B_s mesons are expected to decay predominantly into D_s meson, while the lighter B mesons decay into D_s only about 10% of the time. We exploit this difference to present the first evidence of a substantial production of B_s mesons at the $\Upsilon(5S)$ resonance. We make here a preliminary model dependent estimate of the ratio of $B_s^{(*)}\overline{B}_s^{(*)}$ to the total $b\overline{b}$ quark pair production at the $\Upsilon(5S)$ energy to be $(21 \pm 3 \pm 9)\%$.

1. Introduction

An enhancement in the total e^+e^- annihilation cross-section into hadrons was discovered at CESR long ago^{1, 2, 3} at 10.865 ± 0.008 GeV. This effect was named the $\Upsilon(5S)$ resonance. Potential models⁴ predict the different relative decay rates of the $\Upsilon(5S)$ into combinations of $B^{(*)}\overline{B}^{(*)}$ and $B_s^{(*)}\overline{B}_s^{(*)}$. In a simple spectator model the B_s decays into the D_s nearly all the time. Since the $B \rightarrow D_s X$ branching ratio has already been measured to be $(10.5 \pm 2.6 \pm 2.5)\%$,⁵ we expect a large difference between the D_s yields at the $\Upsilon(5S)$ and the $\Upsilon(4S)$ that we examine in this paper and that can lead to an estimate of the size of the $B_s^{(*)}\overline{B}_s^{(*)}$ component at the $\Upsilon(5S)$. By the $\Upsilon(5S)$ here, we mean the production of any B meson species including B_u , B_d and B_s that occurs at an e^+e^- center-of-mass energy of 10.87 GeV.

2. Analysis Technique

The data sample we used for this analysis consists of 0.42 fb^{-1} of data taken on the $\Upsilon(5S)$ resonance, 6.34 fb^{-1} of data collected on the $\Upsilon(4S)$ and 2.32 fb^{-1} of data taken in the continuum below the $\Upsilon(4S)$. We reconstruct D_s mesons via the $D_s^+ \rightarrow \phi\pi^+$ decay mode using the $\phi \rightarrow K^+K^-$ channel (Charge conjugate decays are implied throughout this paper). Details about track and event selection criteria are available elsewhere.⁴ We consider D_s candidates having a momentum less than or equal to half of the beam energy, the limit from a B decay. To remove at first order differences between continuum data taken just below the $\Upsilon(4S)$, at the $\Upsilon(4S)$ and at the $\Upsilon(5S)$ we choose to work with the variable x which is the D_s momentum divided by the beam energy. The number of signal events is determined by subtracting the

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scaled continuum data below the $\Upsilon(4S)$ from the $\Upsilon(4S)$ and from the $\Upsilon(5S)$ data.⁴ The x dependent D_s detection efficiencies of the two datasets are consistent with each other and have values around 30%.

3. D_s production rates at the $\Upsilon(4S)$ and the $\Upsilon(5S)$

In Fig. 1(a) and 1(b), we show the x distribution of the inclusive D_s yields from the $\Upsilon(4S)$ and the $\Upsilon(5S)$ decays respectively. Using $6,420,910 \pm 5,738 \pm 240,542$

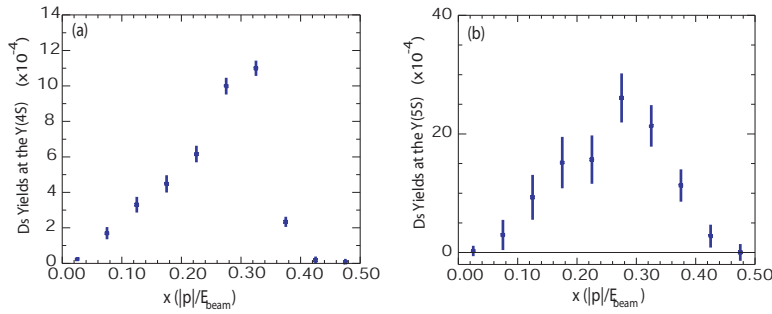


Fig. 1. D_s yields vs x from: (a) the $\Upsilon(4S)$ decays, (b) the $\Upsilon(5S)$ decays. Both plots are continuum subtracted, efficiency corrected, and normalized to the number of resonance events (Preliminary). The partial production rates at the different energies vs. x are available.⁴

of $\Upsilon(4S)$ resonance events and $131,396 \pm 810 \pm 26,546$ of $\Upsilon(5S)$ resonance events above the four-flavor continuum, we find $\mathcal{B}(\Upsilon(4S) \rightarrow D_s X) \cdot \mathcal{B}(D_s \rightarrow \phi\pi) = (8.0 \pm 0.3 \pm 0.4) \cdot 10^{-3}$ and $\mathcal{B}(\Upsilon(5S) \rightarrow D_s X) \cdot \mathcal{B}(D_s \rightarrow \phi\pi) = (20 \pm 2 \pm 4) \cdot 10^{-3}$, thus demonstrating a much larger production of D_s at the $\Upsilon(5S)$ energy than at the $\Upsilon(4S)$, i. e. $\mathcal{B}(\Upsilon(5S) \rightarrow D_s X)/\mathcal{B}(\Upsilon(4S) \rightarrow D_s X) = 2.5 \pm 0.3 \pm 0.6$. Using $\mathcal{B}(D_s \rightarrow \phi\pi^+) = (3.6 \pm 0.9)\%$,⁵ we measure $\mathcal{B}(\Upsilon(4S) \rightarrow D_s X)$ to be $(22.3 \pm 0.7 \pm 5.7)\%$ hence $\mathcal{B}(B \rightarrow D_s X) = (11.1 \pm 0.4 \pm 2.9)\%$ which is in a good agreement with the PDG⁵ value of $(10.5 \pm 2.6 \pm 2.5)\%$. In addition, we find $\mathcal{B}(\Upsilon(5S) \rightarrow D_s X) = (55.0 \pm 5.2 \pm 17.8)\%$.

4. B_s production at the $\Upsilon(5S)$

In Fig. 2, we show the D_s meson yields vs. x from the $\Upsilon(5S)$ with the $\Upsilon(4S)$ spectrum subtracted. The spectrum shows a significant excess of D_s at the $\Upsilon(5S)$, which is a significant evidence for B_s production at the $\Upsilon(5S)$. The branching ratio we measure $\mathcal{B}(B \rightarrow D_s X)$ comes in fact either from the $W^- \rightarrow \bar{c}s$ or from the $b \rightarrow c$ piece if it manages to create an $s\bar{s}$ pair through fragmentation as shown in Fig. 3(a) and 3(b) respectively. Similarly, the production of D_s mesons from B_s decay arises from two dominant processes as well. Fig. 3(c) and 3(d) show a large, possible greater than 100% D_s rate; here the primary $b \rightarrow c$ transition has the charm quark pairing with the spectator anti-strange quark. D_s

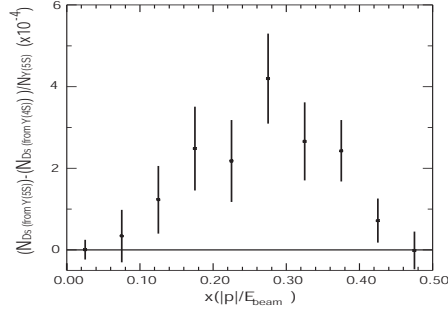
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Fig. 2. The enhancement of D_s yields at the $\Upsilon(5S)$ vs x (no efficiency correction, Preliminary).

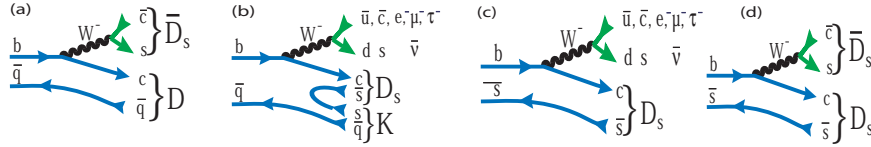


Fig. 3. Dominant decay diagrams for a B and B_s meson into D_s mesons (q can be here either a u or a d quark).

can also be produced from the upper vertex in Fig. 3(c) when the $W^- \rightarrow \bar{c}s$ and these two quarks form a color singlet pair. The chances of this occurring should be similar to the chance of getting an upper-vertex D_s in B decay (Fig. 3(a)). However, It is possible that some D_s are lost from these processes since any $c\bar{s}$ pairs in Fig. 3(c) and 3(d) could fragment into a kaon with a D particle instead of a D_s by producing a $u\bar{u}$ or $d\bar{d}$. These considerations lead to a model dependent estimate of $\mathcal{B}(B_s \rightarrow D_s X) = (92 \pm 11)\%$. Based on this estimate and using the measured product branching fractions $\mathcal{B}(\Upsilon(5S) \rightarrow D_s X) \cdot \mathcal{B}(D_s \rightarrow \phi\pi^+)$ and $\mathcal{B}(\Upsilon(4S) \rightarrow D_s X) \cdot \mathcal{B}(D_s \rightarrow \phi\pi^+)$, we find the ratio of $B_s^{(*)}\bar{B}_s^{(*)}$ to the total $b\bar{b}$ quark pair production at the $\Upsilon(5S)$ energy

$$\mathcal{B}(\Upsilon(5S) \rightarrow B_s^{(*)}\bar{B}_s^{(*)}) = (21 \pm 3 \pm 9)\%$$

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